Journal of
Pulmonology and
Intensive Care

Original Article

DOI: 10.51271/JOPIC-0006

The effect of deep and superficial serratus anterior plane block on postoperative acute pain for thoracoscopic surgery patients; a prospective randomized trial

Musa Zengin[1], Hilal Sazak[2], Oya Kaybal[2], Ramazan Baldemir[2], Gülay Ulger[2], Dilara Arıcan[2], Ali Alagöz[2]

[1]Department of Anesthesiology and Reanimation, Ankara Etlik City Hospital, Ankara, Turkey
[2]Department of Anesthesiology and Reanimation, Ankara Atatürk Sanatorium Training and Research Hospital, University of Health Sciences, Ankara, Turkey

Cite this article: Zengin M, Sazak H, Kaybal O, et al. The effect of deep and superficial serratus anterior plane block on postoperative acute pain for thoracoscopic surgery patients; a prospective randomized trial. *J Pulmonol Intens Care.* 2023;1(2):23-27.

Corresponding Author: Musa Zengin, musazengin@gmail.com

Received: 28/03/2023 ◆ **Accepted**: 04/05/2023 ◆ **Published**: 22/05/2023

ABSTRACT

Aims: In recent years, video-assisted thoracoscopic surgery (VATS) is increasingly preferred over open thoracotomy. Serratus anterior plane block (SAPB) is the preferred analgesic technique in VATS interventions. This study, it was aimed to compare the postoperative analgesic efficacy of superficial SAPB (SSAPB) and deep SAPB (DSAPB) in patients undergoing lung resection with VATS.

Methods: The study was conducted with a prospective, randomized, single-blind design. The ethics committee approval was obtained for the study. The patients, in the age range of 18 to 65 years, with the American Society of Anesthesiologists (ASA) physical status of I-III, and body mass index (BMI) of 18-30 kg/m², and undergoing lung resection with VATS were included in the study. Patients were informed about the study, and their written consent was obtained. Patients were assigned to DSAPB (Group 1) and SSAPB (Group 2) groups according to the analgesia protocol.

Results: After obtaining ethical committee approval, 60 patients were included in the study. Eight patients who converted from VATS to thoracotomy were excluded from the study. There was no statistically significant difference between the groups in terms of demographic characteristics, surgical features, side effects, morphine consumption, and additional analgesic use ($p>0.05$). When the groups were evaluated in terms of the duration of the block procedure, it was found to be statistically significantly longer in the SSAPB group than in the DSAPB group ($p<0.001$).

Conclusion: Both DSAPB and SSAPB were effective and had similar analgesic actions. The shorter block procedure time in DSAPB may be an advantage when considering similar analgesic effects.

Keywords: Acute pain, deep serratus anterior plane block, superficial serratus anterior plane block, video-assisted thoracoscopic surgery.

INTRODUCTION

In recent years, video-assisted thoracoscopic surgery (VATS) is increasingly preferred over open thoracotomy. The popularity of VATS has gradually increased due to the widespread use of applications defined as enhanced recovery after surgery (ERAS), the preference of less invasive surgical techniques, and less associated with postoperative complications.[1,2] Although it is performed via a smaller incision compared to thoracotomy, pain after VATS is still a problem that needs to be resolved. Postoperative severe pain; by making it difficult for the patient to cough, it may cause accumulation of secretions, decrease in functional residual capacity and, as a result, increase in morbidity.[3] Since the formation of postoperative pain depends on tissue damage, preemptive analgesia applications remain on the agenda in the treatment of pain.[4] Although the application of thoracic epidural analgesia (TEA) is considered the gold standard for the treatment of pain in thoracic surgery, in recent years, considering the serious complications associated with TEA application, regional interfacial nerve blocks under ultrasound (US) guidance have been preferred.[5,6] Nowadays, erector spinae plane block (ESPB) and serratus anterior plane block (SAPB) are the most preferred techniques in VATS interventions. The application of such regional blocks is technically easier than TEA or even thoracic paravertebral block (TPVB) and is supported by ERAS protocols besides having lower complication rates.[7]

This work is licensed under a Creative Commons Attribution 4.0 International License.

SAPB is a new technique that provides an analgesic effect by blocking the lateral branch of the intercostal nerve.[8] This block has become a popular analgesic modality as it is easy to administer and relatively safe.[8,9] SABP has two different methods as a deep and superficial application.[8-10] While blocking is applied to the plane between the latissimus dorsi and serratus anterior muscles in superficial SABP (SSAPB); it is applied to the deep plane between the serratus anterior muscle and the rib/external intercostal muscle in deep SABP (DSAPB).[8-10] There are still controversial results about the superiority of these blocks. In VATS applications, publications are showing that SSAPB has a longer and wider blockage area than DSAPB, and there are also publications in the literature showing that these two methods are not superior to each other.[8-10]

We hypothesized that SAPB may be effective in reducing postoperative pain in patients undergoing VATS and that SSAPB or DSAPB methods may exhibit different properties. It was aimed to compare the postoperative analgesic efficacy and application times of SSAPB and DSAPB in patients undergoing lung resection with VATS. The VAS pain scores during the first 48 hours after surgery were determined as the primary outcome. The 24-hour morphine consumption, additional analgesic requirements, and block performance time were of the patients were determined as the secondary outcome.

METHODS

The randomized and prospective trial was conducted in a high-volume tertiary thoracic surgery center after obtaining approval from Ankara City Hospital Ethics Committee (Date: 22.10.2021, Decision No: E1-21-2067). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. The patients, in the age range of 18 to 65 years, with the American Society of Anesthesiologists (ASA) physical status of I-III, and body mass index (BMI) of 18-30 kg/m², and undergoing lung resection with VATS were included in the study. Patients were informed about the study, and their written consent was obtained.

During the preoperative evaluation, the patients were informed about pain assessment and patient-controlled analgesia (PCA). Patients with preoperative acute or chronic pain and a history of opioid therapy were excluded. Moreover, patients with bleeding disorders, infection at the injection site, or allergy to local anesthetics, and patients who underwent emergency surgery were excluded from the study. In addition, patients who converted from VATS to thoracotomy were also excluded from the study.

Patients were divided into DSAPB (Group 1) and SSAPB (Group 2) groups according to the analgesia protocol. Randomization was achieved with computer-generated random numbers.

Patients were monitored in the operating room following the ASA standards. Patients were administered 0.03 mg/kg midazolam for premedication. Following preoxygenation, anesthesia was induced with 2 mg/kg propofol, 1 mcg/kg fentanyl, and 0.1 mg/kg vecuronium. After intubation with a left-sided double-lumen endobronchial tube, tube localization was confirmed. Anesthesia was maintained with sevoflurane in a mixture of oxygen and air. Additionally, remifentanil infusion at a dose of 0.01-0.20 mcg/kg/min was administered.

Block procedures were performed under general anesthesia before the skin incision to prevent anxiety and ensure patient comfort. Following the anesthesia induction, blocks were performed under US guidance when patients were in the lateral decubitus position. After strict skin antisepsis, the needle insertion area was covered with sterile drapes. A high-frequency 6–18 MHz linear probe (MyLab six, Esaote, Genoa, Italy) in a sterile cover and a US-compatible 22-gauge and 8-mm nerve block needle (Pajunk, SonoPlexSTIM, Germany) were used in all groups. Block performance times were noted based on the entry of the block needle into the skin and the exit of the needle after the block. The following procedures were performed in the study groups:

DSAPB group (n:30): Following the visualization of the anatomical structures, the nerve block needle was advanced via the in-plane technique until reaching the fourth rib. Hydrodissection with 2 ml of normal saline was performed beneath the serratus anterior muscle, and a volume of 20 ml of 0.25% bupivacaine was injected into the area (**Figure 1**).

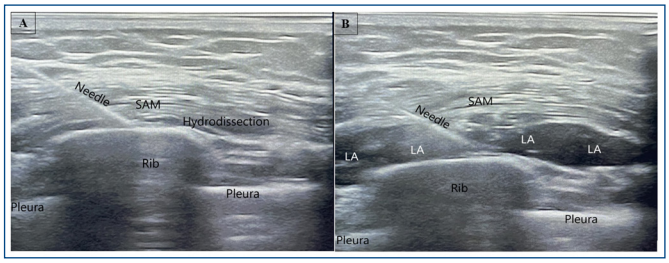

Figure 1. Deep serratus anterior plan block procedure. A: Anatomical scene before the block and hydrodissection with 2 ml of saline solution was performed into the interfascial plane above the rib and below the SAM. B: Deep serratus anterior plan block; The local anesthetic spread beneath the serratus anterior muscle. SAM: serratus anterior muscle, LA: local anesthetic.

SSAPB group (n: 30): After the visualization of the anatomical structures, the needle was advanced via the in-plane technique above the serratus anterior muscle; hydro dissection with 2 ml of normal saline was performed in the interfascial space, and a volume of 20 ml of 0.25% bupivacaine was injected into the area (**Figure 2**).

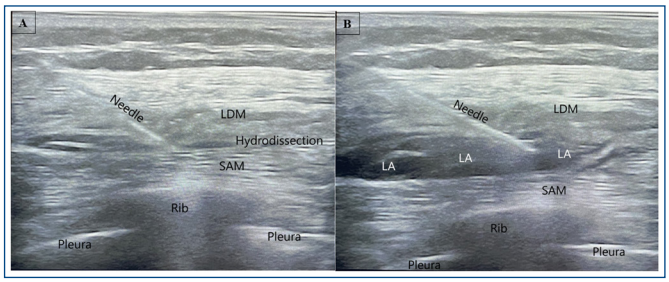

Figure 2: Superficial serratus anterior plan block procedure. A: Anatomical scene before the block and hydrodissection with 2 ml of saline solution was performed into the interfascial plane above the SAM and below the LDM. B: Superficial serratus anterior plan block; The local anesthetic spread above the serratus anterior muscle. LA: local anesthetic, LDM: Latissimus Dorsi Muscle, SAM: serratus anterior muscle.

During the skin closure, patients received dexketoprofen and tramadol intravenously. Metoclopramide was administered intravenously to avoid nausea and vomiting. In the postoperative surgical intensive care unit, intravenous morphine was administered via PCA pump for 24 hours. Pain intensity was evaluated using a 10- point (0: No pain and 10: Unbearable pain) visual analog scale (VAS). The PCA pump's dose delivery was limited to administering a

bolus dose of 1 mg morphine and delivering a maximum dose of 12 mg morphine in total within 4 hours with lockout intervals of 15 minutes. Paracetamol 1 g every 8 hours and dexketoprofen 50 mg twice daily were administered intravenously for multimodal analgesia. As a rescue analgesic agent, 0.5 mg/kg tramadol was given to patients intravenously when a score of VAS at rest was ≥4. The patients were transferred to the ward in the postoperative 24th hour. Paracetamol 500 mg tablets and tramadol 50 mg capsules every 8 hours and dexketoprofen 25 mg tablets every 12 hours were given after the postoperative second day. VAS scores at rest and while coughing were recorded in the postoperative 1st hour, 2nd hour, 4th hour, 8th hour, 16th hour, 24th hour, and 48th hour. The need for additional analgesics and side effects including allergic reactions, respiratory depression, sedation, hypotension, urinary retention, nausea-vomiting, and itching were recorded. In two groups, patients' hemodynamic data, age, BMI, gender, diagnosis, the type of surgery, intraoperative and postoperative complications, postoperative VAS scores, and postoperative additional analgesic use were recorded. The block was applied to all patients by the same attending anesthesiologist. The VAS score was followed up by the pain management nurse who was blinded to the type of block applied to the patient. All VATS procedures were applied by the same surgical team with sufficient experience in this regard in the third-level thoracic surgery center. A single polyvinylchloride chest tube was introduced, made of two openings, a camera port, and a utility.

Data analyses were performed by using SPSS for Windows, version 22.0 (SPSS Inc., Chicago, IL, United States). Whether the distribution of continuous variables was normal or not was determined by the Kolmogorov Smirnov test. Levene test was used for the evaluation of homogeneity of variances. Unless specified otherwise, continuous data were described as mean ± SD for normal distributions, and median (interquartile range). for skewed distributions. Categorical data were described as a number of cases (%). Statistical analysis differences in normally distributed variables between two independent groups were compared by Student's t-test, Mann Whitney U test was applied for comparisons of the not normally distributed data. Categorical variables were compared using Pearson's chi-square test or fisher's exact test was accepted p-value <0.05 as a significant level on all statistical analysis.

The sample size was calculated using G*Power© software version 3.1.9.2 (Institute of Experimental Psychology, Heinrich Heine University, Dusseldorf, Germany). The sample size was calculated for the mann whitney u-test, which was used for testing the main hypothesis of (VAS scores at rest in the first postoperative hour) the present study. Depending on previous research results with two-sided (two tails) type I error 0.05 and power of 80% (1-β=0.8), effect size (d) factor 0.88, should involve ≥ 44 subject.

RESULTS

After obtaining ethical committee approval, 60 patients were included in the study. Eight patients who converted from VATS to thoracotomy were excluded from the study. (**Figure 3**).

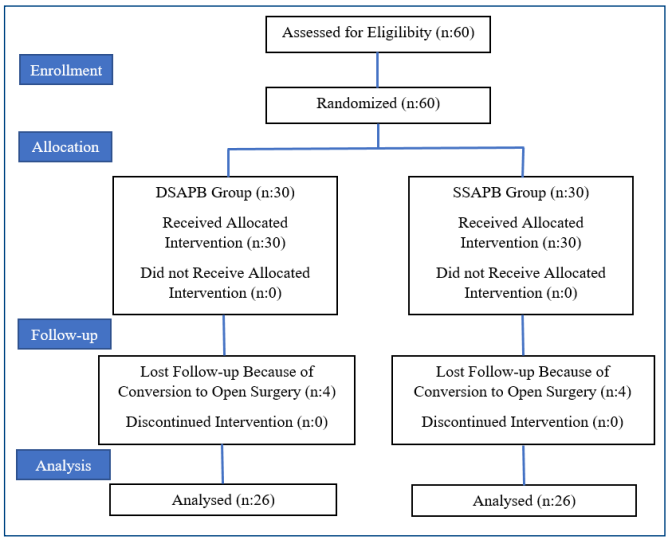

Figure 3: Flow Chart. DSAPB: Deep Serratus Anterior Plane Block, SSAPB: Superficial Serratus Anterior Plane Block

There was no statistically significant difference between the groups in terms of demographic characteristics, surgical features, side effects, morphine consumption, and additional analgesic use (p>0.05) (**Table 1**).

Table 1: Demographic characteristics, surgical features, side effects, remifentanil consumption, morphine consumption, additional analgesic use, duration of the block procedure of the patients.

	DSAPB (n:26)	SSAPB (n:26)	p
Age (year)	51.5 (15)	53.5 (19)	0.905$^{\beta}$
Gender			0.999$^{\delta}$
Female	7 (26.9%)	7 (26.9%)	
Male	19 (73.1%)	19 (73.1%)	
BMI	25.7 (6.5)	24.45 (5.9)	0.458$^{\beta}$
Operation			0.999$^{\delta}$
Wedge	23 (88.5%)	23 (88.5%)	
Lobectomy	3 (11.5%)	3 (11.5%)	
Duration of operation (minute)	180 (60)	150(60)	0.599$^{\beta}$
Block performance time (second)	118.19 ± 11.92	134,65±8,63	<0.001*
ASA			0.578$^{\delta}$
ASA II	13 (50.0%)	15 (57.7%)	
ASA III	13 (50.0%)	11 (42.3%)	
Nausea, Yes	4 (15.4%)	3 (11.5%)	0.999$^{\delta}$
Additional analgesic use, Yes	9 (34.6%)	6 (23.1%)	0.358$^{\delta}$
Intraoperative remifentanil consumption (mcg)	420.00±175.45	411.15±141.29	0.842*
Morphine consumption (mg)	21.35±12.87	18.62±10.89	0.413*

Continuous variables are expressed as either * the mean ± standard deviation (SD) or β the median ((interquartile range), and categorical variables are expressed as either δ frequency or percentage. Continuous variables were compared with an student T Test or the Mann Whitney U Test, and categorical variables were compared using Pearson's Chi-Square Test or Fisher Exact Test. Statistically significant p-values are in bold. BMI: Body mass index. ASA: American Society of Anesthesiologist.

When the groups were evaluated in terms of the block performance time, it was found to be statistically significantly longer in the SSAPB group than in the DSAPB group (p< 0.001) (**Table 1**).

No statistically significant difference was observed between the groups in terms of hemodynamic parameters and SpO_2 (p >0.05).

There was no statistically significant difference between the groups in terms of all VAS resting and VAS coughing (p>0.05) (**Figure 4**) (**Table 2**).

Table 2: Resting and coughing VAS scores during the postoperative 48 hours.

	DSAPB (n:26)	SSAPB (n:26)	p
	Med (IQR)	Med (IQR)	
VAS at rest			
1st hour	3 (2)	3 (1)	0.430
2nd hour	2,5 (2)	2 (1)	0.726
4th hour	2 (2)	2 (2)	0.832
8th hour	2 (2)	2 (1)	0.977
16th hour	1 (1)	1 (1)	0.530
24th hour	1 (1)	1 (2)	0.520
48th hour	2 (2)	2 (2)	0.748
VAS at cough			
1st hour	4 (2)	4 (2)	0.468
2nd hour	4 (2)	3 (2)	0.748
4th hour	3 (2)	3 (2)	0.895
8th hour	3 (2)	3 (1)	0.682
16th hour	2 (1)	2.5 (1)	0.938
24th hour	2 (1)	2 (2)	0.621
48th hour	3 (1)	3 (2)	0.621

Continuous variables are expressed as the median (interquartile range). Continuous variables were compared with the Mann-Whitney U test. Statistically significant p-values are in bold.

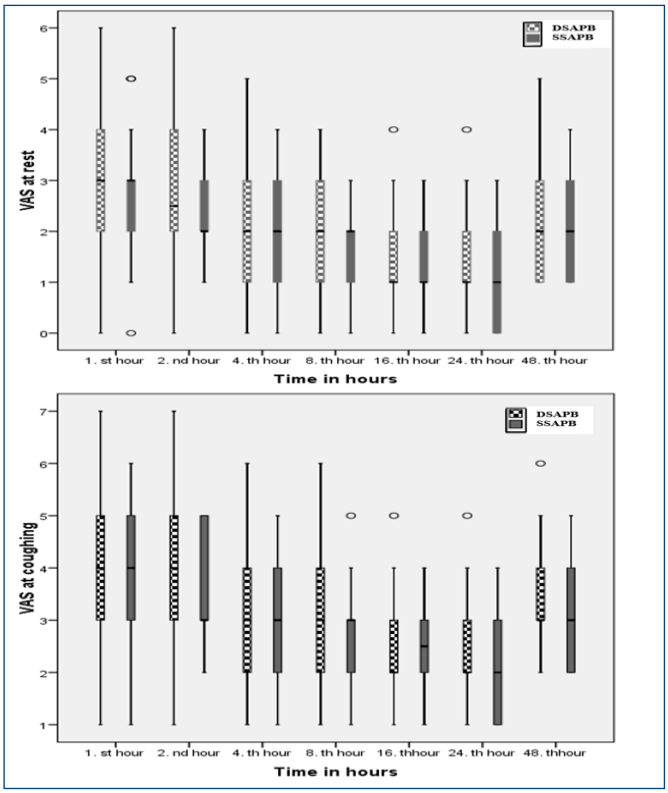

Figure 4: VAS scores at rest and VAS scores at coughing. Data are expressed as median (horizontal bars), interquartile range (boxes), and maximum and minimum values (whiskers) for the VAS scores in the 1st, 2nd, 4th, 8th, 16th, 24th hours, and 48th hours. DSAPB: Deep Serratus Anterior Plane Block, SSAPB: Superficial Serratus Anterior Plane Block, VAS: Visual analog scale.

DISCUSSION

The results of this study showed that both DSAPB and SSAPB provided effective postoperative analgesia in patients who underwent VATS. Although their analgesic effects are similar, the shorter block performance time in DSAPB can be considered as an advantage of this practice.

In recent years, VATS has become an increasingly preferred method in lung resections because it is a less invasive treatment method.[1] Although the pain is more limited compared to thoracotomy, severe pain may be encountered, especially in the first 24 hours postoperatively, and this may last longer.[3,8] Poorly controlled postoperative pain may limit the patient's effective coughing function, resulting in pulmonary infections and delayed recovery.[3] Various analgesic methods are used to relieve pain after VATS, techniques such as TPVB, ESPB, SSAPP, and DSAPB have been increasingly used recently.[7] These applications are also one of the most important elements of multimodal analgesia, which is a component of ERAS protocols, the main concept of which aims to accelerate the surgical process with the least invasive intervention possible.[7] In addition, TPVB, ESPB, and SAPB have recently been recommended by the European Society of Regional Anaesthesia (ESRA) as methods of choice for postoperative analgesia after VATS (recommendation grade: A, for all 3 techniques).[11] SAPB application seems to be more practical and safe due to the relative difficulty of TPVB and ESPB application, and the proximity to the pleura and vascular structures, especially in TPVB. In addition, studies have revealed that similar results in terms of postoperative analgesia are obtained with TPVB and ESPB in SAPB applications. Anatomically, the serratus anterior muscle originates on the surface of the first 8 ribs and attaches to the medial border of the scapula and posterior aspect of the latissimus dorsi. Intercostal nerves pierce the muscle and pass through the deep and anterior planes of the serratus anterior muscle in transition to the subcutaneous tissue.[12] This anatomical location may provide adequate analgesia effect at T2 to T9 levels in patients undergoing SAPB. Another advantage of SAPB applications is that they are easier to view and easier to implement than TPVB and ESPB.[8]

Studies comparing the analgesic efficacy of DSAPB and SSAPB after VATS are very limited.[8-10] Blanco et al.[9] argued that SSAPB has a wider block area in their study. While Piracha et al.[13] found that DSAPB could offer better analgesia compared to superficial injection in four patients undergoing breast surgery, Abdallah et al.[14] found similar analgesic effects with both plane blocks after breast surgery. On the other hand, a study by Qui et al.[8] showed that superficial SAPB is more effective. The widespread use of local anesthesia in the deep or superficial block is still controversial. Biswas et al.[15] in a cadaver study, with a high-volume injection technique, provided widespread and consistent dye distribution in the anterior chest wall and axilla, regardless of superficial or deep application. However, they stated that its distribution in the posterior area is more limited. Qui et al.[8] showed in their study that SSAPB creates a more effective block compared to DSAPB. The authors argued that this situation may be related to complete or partial blockage of the long thoracic nerve innervating the serratus anterior muscle with SSAPB. It was evaluated as this blockade provided more effective analgesia by blocking the anterior branches of the intercostal nerves. In this study, we observed similar analgesic actions with both SSAPB and DSAPB in the postoperative 48-hour period.

There is no consensus on the ideal local anesthetic injection volume for SAPB. Major studies on this subject are at the level of cadaver or imaging studies.[15,16] Kunigo et al.[17] compared SAPB applications using 20 mL and 40 mL of ropivacaine for postoperative analgesia after breast cancer surgery and found that higher volume produced a better analgesic effect and that the blocking effect could be sufficient and safer with lower doses also. In this study where we kept the local anesthetic volume constant at 20 ml, we achieved sufficient analgesic effect.

Block performance times are important in terms of showing the easy applicability of the block. This is important not only for limiting the time spent on the block but also for the convenience of the process. In studies on SAPB applications, the block procedure duration has not come to the fore.[8-14] However, Edwards et al.[18] evaluated DSAPB and SSAPB in terms of the duration of the block procedure in patients who underwent breast surgery and found the duration of block application to be shorter in patients who underwent DSAPB. In our study, the DSAPB application was completed in a shorter time than the superficial application. This can be explained by the rapid acquisition of the ultrasound image due to the rib and the fact that the deep serratus region is less mobile due to its proximity to the rib during application. In addition to providing similar analgesic effects with SSAPB, we think that DSAPB, which can be administered in a shorter time, may be a good alternative to SSAPB. Moreover, we think that since the area where DSAPB is applied is directly above the rib and away from the pleura, it will not pose a problem in terms of safe block application.

Qui et al.[8] found that the number of patients who developed nausea and vomiting in patients who underwent SSAPB was higher without significance after VATS. In this study, we observed only nausea as a side effect in the DSAPB and SSAPB groups. However, although this rate was higher in the SSAPB group, there was no significant difference between the groups. Considering that many factors are effective in the development of PONV after surgery, it may not be possible to evaluate whether the applied blocks may be related to PONV.

The present study has some limitations. The study was conducted at a single center. In the study, the block was applied using the same local anesthetic volumes in both blocks. Studies with different volumes may be useful in evaluating the effect on block quality. In addition, the long-term analgesic effects of these two blocks could not be evaluated in this study.

CONCLUSION

In this study comparing DSAPB and SSAPB in patients who underwent VATS lung resection, safe and effective analgesia was obtained with both blocks. Although their analgesic effects are similar, the shorter block procedure time in DSAPB can be considered as an advantage of this practice.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Ankara City Hospital Ethics Committee (Date: 22.10.2021, Decision No: E1-21-2067).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Wu N, Wu L, Qiu C, et al. A comparison of video-assisted thoracoscopic surgery with open thoracotomy for the management of chest trauma:a systematic review and meta-analysis. *World J Surg.* 2015;39(4):940-952. doi:10.1007/s00268-014-2900-9
2. Flores RM, Park BJ, Dycoco J, et al. Lobectomy by video-assisted thoracic surgery (VATS) versus thoracotomy for lung cancer. *J Thorac Cardiovasc Surg.* 2009;138(1):11-18. doi:10.1016/j.jtcvs.2009.03.030
3. Łochowski MP, Kozak J. Video-assisted thoracic surgery complications. *Wideochir Inne Tech Maloinwazyjne.* 2014;9(4):495-500. doi:10.5114/wiitm.2014.44250
4. Neustein SM, McCormick PJ. Postoperative analgesia after minimally invasive thoracoscopy: what should we do? *Can J Anaesth.* 2011;58(5):423-427. doi:10.1007/s12630-011-9475-9
5. Loop T. Fast track in thoracic surgery and anaesthesia: update of concepts. *Curr Opin Anaesthesiol.* 2016;29(1):20-5. doi:10.1097/ACO.0000000000000282
6. Hamilton DL, Manickam B. Erector spinae plane block for pain relief in rib fractures. *Br J Anaesth.* 2017;118(3):474-475. doi:10.1093/bja/aex013
7. Kaplowitz J, Papadakos PJ. Acute pain management for video-assisted thoracoscopic surgery:an update. *J CardiothoracVascAnesth.* 2012;26(2):312-321. doi:10.1053/j.jvca.2011.04.010
8. Qiu L, Bu X, Shen J, et al. Observation of the analgesic effect of superficial or deep anterior serratus plane block on patients undergoing thoracoscopic lobectomy. *Medicine (Baltimore).* 2021;100(3):e24352. doi:10.1097/MD.0000000000024352
9. Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block:a novel ultrasound-guided thoracic wall nerve block. *Anaesthesia.* 2013;68(11):1107-13. doi:10.1111/anae.12344
10. Moon S, Lee J, Kim H, Kim J, Kim J, Kim S. Comparison of the intraoperative analgesic efficacy between ultrasound-guided deep and superficial serratus anterior plane block during video-assisted thoracoscopic lobectomy: a prospective randomized clinical trial. *Medicine (Baltimore).* 2020;99(47):e23214. doi:10.1097/MD.0000000000023214
11. Feray S, Lubach J, Joshi GP, Bonnet F, Van de Velde M; PROSPECT Working Group *of the European Society of Regional Anaesthesia and Pain Therapy. PROSPECT guidelines for video-assisted thoracoscopic surgery: a systematic review and procedure-specific postoperative pain management recommendations. *Anaesthesia.* 2022;77(3):311-325. doi:10.1111/anae.15609
12. Willard FH, Vleeming A, Schuenke MD, Danneels L, Schleip R. The thoracolumbar fascia:anatomy, function and clinical considerations. *J Anat.* 2012;221(6):507-536. doi:10.1111/j.1469-7580.2012.01511.x
13. Piracha MM, Thorp SL, Puttanniah V, Gulati A. "A tale of two planes": deep versus superficial serratus plane block for postmastectomy pain syndrome. *Reg Anesth Pain Med.* 2017;42(2):259-262. doi:10.1097/AAP.0000000000000555
14. Abdallah FW, Cil T, MacLean D, et al. Too deep or not too deep?: a propensity-matched comparison of the analgesic effects of a superficial versus deep serratus fascial plane block for ambulatory breast cancer surgery. *RegAnesth Pain Med.* 2018;43(5):480-487. doi:10.1097/AAP.0000000000000768
15. Biswas A, Castanov V, Li Z, et al. Serratus plane block:a cadaveric study to evaluate optimal injectate spread. *RegAnesth Pain Med.* 2018 ov;43(8):854-858. doi:10.1097/AAP.0000000000000848
16. Kunigo T, Murouchi T, Yamamoto S, Yamakage M. Spread of injectate in ultrasound-guided serratus plane block:a cadaveric study. *JA Clin Rep.* 2018;4(1):10. doi:10.1186/s40981-018-0147-4
17. Kunigo T, Murouchi T, Yamamoto S, Yamakage M. Injection volume and anesthetic effect in serratus plane block. *RegAnesth Pain Med.* 2017;42(6):737-740. doi:10.1097/AAP.0000000000000649
18. Edwards JT, Langridge XT, Cheng GS, McBroom MM, Minhajuddin A, Machi AT. Superficial vs. deep serratus anterior plane block for analgesia in patients undergoing mastectomy: a randomized prospective trial. *J Clin Anesth.* 2021;75:110470. doi:10.1016/j.jclinane.2021.110470